The Bats of Central and Western India

PART IV

BY

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(*With three text-figures*)

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This fourth and last part deals with certain general aspects of the biology of Indian bats, mainly their zoo-geographical affinities, ecology, reproduction, and hibernation. More detailed papers on their reproduction and hibernation are under preparation and only a a summary is given here.

ZOO-GEOGRAPHICAL AFFINITIES OF INDIAN BATS

The theories concerning the zoo-geographical origin of the different species of bats admit of a large amount of speculative uncertainty. However, if we consider, not the species or even the genus one by one but, the whole fauna of bats of a given area, their zoo-geographical affinities appear more clearly. Table I below gives the general distribution of the genera represented in western and central India. Most of these genera have an immense area of distribution; not a single one is specifically Indian. This table shows that it is not possible to deduce the affinities of Indian species from the examination of the distribution of the genus. Table II shows the distribution of the Indian bats at species level. The zoo-geographical affinities of the Indian bats appear clearly at this level and Indian species can be classified in several groups:

(i) *Species having their centre of distribution in the deserts of Africa and Asia:* The two species of *Rhinopoma* and probably *Taphozous kachhensis.*

(ii) *Species having their centre of distribution in the arid areas of eastern Africa:* They are *Taphozous perforatus* and *Tadarida aegyptiaca.*

TABLE I

GENERAL DISTRIBUTION OF THE GENERA OF BATS IN WESTERN AND CENTRAL INDIA

Rousettus	*Pteropus*	*Cynopterus*	*Taphozous*	*Rhinopoma*
Tropical Asia and Africa.	Tropical Asia, Madagascar, Australia.	Southern Asia and Malaya.	Tropical Asia and Africa.	Arid areas of Asia and Africa.
Megaderma	*Rhinolophus*	*Hipposideros*	*Tadarida*	*Otomops*
Southern Asia with closely allied genera in Africa and Oceania.	Practically all over the Old World.	Tropical Asia and Africa.	Tropical and arid countries of the five continents.	Tropical Asia and Africa, Madagascar, and Oceania.
Pipistrellus	*Hesperoptenus*	*Scotophilus*	*Tylonycteris*	*Myotis*
The whole Old World and North America.	Southern Asia.	Tropical Asia and Africa.	Tropical Asia.	Practically the whole world.
Miniopterus	*Kerivoula*			
Europe, Asia, Africa, Oceania.	Tropical Asia and Africa.	..	..	..

TABLE II

GENERAL DISTRIBUTION OF THE SPECIES OF BATS OF WESTERN AND CENTRAL INDIA.

Rousettus leschenaulti India to Indo-China and Java.	*Pteropus giganteus* India, Burma, and Ceylon.	*Cynopterus sphinx* India to Java.	*Rhinopoma microphyllum* Deserts and tropical arid areas of the Old World.
Rhinopoma hardwickei Perhaps the whole Sahara, deserts of Asia, Egypt, the greater part of India, Siam.	*Taphozous perforatus* Arid areas of eastern Africa, deserts of Asia to Gujarat.	*Taphozous melanopogon* India to Borneo.	*Taphozous saccolaimus* India to Sumatra.
Taphozous theobaldi India to Java.	*Taphozous kachhensis* Perhaps various parts of the deserts of the Old World, India, Malaya.	*Taphozous longimanus* India to Borneo.	*Megaderma spasma* India to Borneo.
Megaderma lyra India and Burma.	*Hipposideros bicolor* India to Formosa.	*Hipposideros speoris* India to Borneo.	*Hipposideros lankadiva* India and Ceylon.
Hipposideros galeritus India to Borneo.	*Rhinolophus rouxi* India and south of China.	*Rhinolophus lepidus* India and Malaya.	*Rhinolophus luctus* India and Borneo.
Tadarida aegyptiaca Egypt, Kenya, western India.	*Otomops wroughtoni* India.	*Pipistrellus mimus* India and Annam.	*Pipistrellus coromandra* India and Indo-China.
Hesperoptenus tickelli India and Ceylon.	*Pipistrellus ceylonicus* India to Indo-China.	*Pipistrellus dormeri* India to Formosa.	*Myotis peytoni* and *M. peshwa* India.
Kerivoula picta India to Borneo.	*Tylonycteris pachypus* India to Sumatra.	*Scotophilus kuhli* and *S. wroughtoni* India to eastern Asia.	*Miniopterus schreibersi* France to Australia.

(iii) *Species having their centre of distribution in south-eastern Asia:* They are the great majority. *Rousettus leschenaulti, Pteropus giganteus, Cynopterus sphinx, Taphozous melanopogon, T. saccolaimus, T. theobaldi,* and *T. longimanus, Megaderma spasma,* and *M. lyra, Hipposideros bicolor, H. speoris, H. lankadiva,* and *H. galeritus, Rhinolophus rouxi, R. lepidus,* and *R. luctus, Pipistrellus mimus, P. ceylonicus, P. coromandra,* and *P. dormeri, Hesperoptenus tickelli, Kerivoula picta, Tylonycteris pachypus,* and *Scotophilus kuhli,* and *S. wroughtoni.*

(iv) *Purely Indian species: Myotis peshwa* and *M. peytoni,* and *Otomops wroughtoni.* These species are rare and perhaps inhabit other areas, where they have not been studied.

(v) *Cosmopolitan species:* A single one—*Miniopterus schreibersi.*

The bats in India appear to be essentially oriental, with a few species originally from eastern Africa and the deserts of the tropical areas of the Old World. India forms the meeting place between two types of fauna, the bats from Rajasthan, Gujarat, and western Madhya Pradesh belonging to the western world, and the rest of the country being inhabited by oriental species. This difference is evidently determined by ecology—north-western India forming the eastern border of this immense arid area extending eastwards from Mauritania, the rest of the country belonging to the oriental region of Asia.

It may be noted that the zoo-geographical origin of bats in India recalls that of birds in the same area (cf. Dillon Ripley). It would appear that these two groups of flying vertebrates evolved along parallel lines adapting themselves to prevalent ecological conditions.

Ecology

Every nocturnal species has two kinds of biotopes: the diurnal roost, where the individuals rest and sleep, and the nocturnal territory where they search for their food. According to the species, their social activities occur in the diurnal or the nocturnal territory. Most species of bats have very precise requirements for both diurnal and nocturnal biotopes.

(*a*) The diurnal roost: The existence of suitable diurnal biotopes is a very important factor in the ecology of bats. In India species living in cracks and trees easily find shelter. But the highly gregarious species, which live in cavities in large colonies, need caves

or decayed buildings, which do not exist all over the country. The abundance or absence of species like *Taphozous*, for instance, is linked with the presence of old palaces, hypogean temples, or cliffs with large crevices.

Indian bats have two types of roosting biotope: cavities, and the open air.

1. Cavities

Four types of cavity are inhabited by Indian species: (a) caves; (b) deserted buildings; (c) crevices of cliffs, walls, and wooden structures; and (d) hollows in trees.

(a & b) *Caves and deserted buildings:* The same species inhabit caves and the interior of buildings and are of the genera *Taphozous*, *Rhinopoma*, *Rhinolophus*, *Hipposideros*, and *Megaderma*. During the day, they hang by their hind limbs from the ceilings like cocoons (*Rhinolophus*, *Hipposideros*), or keep themselves hooked by the fore limbs against the walls (*Taphozous*).

The artificial caves carved by the Hindus and the Buddhists have provided many suitable biotopes. In fact, natural caves do not occur in the coastal areas and in the Deccan. Before the caves and temples were made by man, the species of *Taphozous*, *Rhinopoma*, and *Megaderma* only had the cracks in the cliffs, which are not numerous in western India, as their diurnal roosts. But now, probably over many centuries, these species have no doubt occupied the many artificial caves and hypogean temples, which today form the most suitable and accessible places in India in which to study them.

Let us see what are the factors favourable to the settlement of bats in caves and buildings. A large cavity is not a strict necessity, and the size of the room is of secondary importance. For instance, I saw in Chikalda hundreds of *Rousettus* roosting under the dome of a small isolated dungeon. The whole surface of the ceiling was covered with bats. In the cave at Alibag, *Taphozous melanopogon* were in low recesses, almost at the level of the ground. Colonies of *Hipposideros* have been observed in holes of foxes and porcupines. But an important factor is the existence near by of other caves where the bats may find shelter when they are disturbed during the day in the main habitat. In fact, if bats like *Rousettus* or *Hipposideros* are chased from a cave into the open air, they are attacked by kites and crows and must quickly reach another place of safety. For this reason, large colonies are most often found where the caves are numerous, with ramifications and recesses.

This darkness is no doubt a favourable factor, but perhaps more important is the quietness which usually prevails in dark places. For instance, the colonies of *Rhinopoma microphyllum* of western India spend the day in well-lit porches, at the entrances of caves and ruins. They take shelter in the darker parts of the diurnal habitat only if they are disturbed. Similar observations may be true of *Taphozous* and *Megaderma.*

A high degree of humidity is required by the palaearctic species living in caves, and they do not frequent the dry cavities. This need of humidity is certainly connected with periods of hibernation which may extend to six months and more in cold countries. In India, these conditions do not exist and many species live in relatively dry cavities. *Rhinolophus rouxi* appeared to be an exception, and was always found in humid caves. Generally speaking the Rhinolophids are known for the fragility of their wing membranes; if the bat is kept in dry air, the wing membranes dry quickly and the bat dies.

Tranquillity affects different species differently. *Rousettus leschenaulti* is very intolerant and abandons its diurnal roost easily and definitely if it is disturbed. Twenty years ago, the colony at Khandala deserted the railway tunnel after Br. Navarro took some specimens there. In 1961, the Archaeological Department carried out some work in the vicinity of the large colony at Elephanta with the same result.

On the other hand, the elimination of *Taphozous* and *Rhinopoma* from the caves of archaeological interest is a difficult enterprise. These species refuse to abandon their diurnal roosts, even when much disturbed. The cracks and other small inaccessible cavities adjacent to the main caves or hypogean temples give temporary shelter to the disturbed members, which return to the original place as soon as the immediate cause of disturbance has passed. Many well-known places, e.g. Ellora, Ajanta, and Agra, are full of *Taphozous*, and the Archaeological Department have been unable to do anything better than continue to pay numerous scavengers to sweep away the guano.

Finally, we may say that bats in India can be found in all types of caves and old buildings. Caves are relatively not numerous in India and, the choice being restricted, practically every cavity gives shelter to populations of bats.

(c) *Cracks and crevices:* This type of biotope is peculiar to a group of species which need to have both their back and belly closely in contact with the surface of the wood or the stone. This 'chasmotropism' is usual in the Molossid family (*Tadarida, Otomops*).

The individuals of these species introduce themselves in narrow crevices of the buildings, cliffs, ceilings of caves, timber work, etc., and their reactions to disturbance is not to fly away, but to draw back into the deeper parts of the cracks or crevices. Similar habitat and behaviour are also characteristic of several Vespertilionidae, e.g. *Pipistrellus*, *Scotophilus*, *Myotis*, etc.

For instance, the *Pipistrellus*, which are far the most numerous and the commonest bats of India and of the Old World, live in the roofs of buildings especially under the tiles, and also under the blinds, behind picture frames on the walls, etc. *Tadarida aegyptiaca* inhabits deep crevices of the cliffs (Aurangabad) or of old buildings (Poona, Mandu, Agra). Humayun Abdulali told me that he had found one specimen of *Tadarida* sp. (?) on the ground, under a stone on a small islet off the Malwan Coast, south of Bombay[1]. Such type of biotope, although probably rare in India, is well known in certain African bats of the same genus. *Otomops wroughtoni* inhabits deep crevices and the upper portion of large funnels in the ceiling of Barapede Cave. This heavy bat has very narrow wings, and has to let itself drop down from a height before it can fly off. Usually the species of the genus *Tadarida* have the same requirements.

The *Pipistrellus* are much more numerous around villages and towns than in the country. They have taken great advantage of man's presence by colonizing his houses. All these species have little to fear from human beings. The owners of the houses inhabited by *Pipistrellus* pay no attention to their presence. *Tadarida* and *Otomops* are not common species in India; they are difficult to find and to capture, and human interference in their life is very rare.

(d) *Hollow trees:* In various parts of the world, hollows in trees form the normal diurnal roost for many species of bats. I have myself had the opportunity to verify this in Africa and South America. In India, except perhaps in large forests, this is not so, and the bats inhabiting decayed or hollow trees are few. Some *Pipistrellus* were observed in crevices of tree trunks, and a few observations show that *Taphozous saccolaimus* spend the day in decayed palm trees. In Kanara, Shortridge found two species of *Rhinolophus* in hollows of trees. *Tylonycteris pachypus* is known to roost inside decayed bamboos.

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[1] In Vol. 26 of the *Journal* at p. 824 Inglis *et al.* in ' A tentative list of the vertebrates of the Jalpaiguri District, Bengal ' record *Myotis muricola* as common ' under stones in the bed of the Torsa river '.—Eds.

2. **Open air**

In Central and South America, numerous species inhabit the open air during the day: surface of rocks, foliage, branches of trees, etc. In the Old World, this type of biotope concerns only a few species, none in the palaearctic, perhaps a dozen in Africa, and only three or four in India. The best known is *Pteropus giganteus*, an arboreal species, very common everywhere, especially on trees in the middle of villages. In Gujarat, *Taphozous longimanus* often roost on the external walls of houses. Finally it seems that *Kerivoula picta* and *Hesperoptenus tickelli* live in trees, probably concealed among the leaves during the day, but precise information is not available.

(*b*) The nocturnal feeding territory: According to the ornithologists, competition for food between the various species of birds living in a given area is unimportant, or even non-existent, because each species has its own type of food or has a special feeding area and does not encroach into the territory of the others. The rule does not seem true everywhere, especially in the tropical forests of America (or even of India) where numerous closely allied species of birds having a similar morphology and diet live side by side. Nevertheless, the theory of Ecological Niches is useful and helps to explain the exploitation of the food available in a given biotope.

During the night, the hunting territories of birds are occupied by the bats. Have they in the same manner exploited the various possibilities of the biotope for their food? Are their morphological differences associated with their special diet or methods of hunting as in the birds? An affirmative reply can be given to both questions.

The hunting territories of insectivorous Indian bats are of three main types: (a) the open air; (b) amid the foliage of trees; and (c) on the surface of rocks and on the bark of trees.

The frugivorous species have two types of feeding territory, not so well marked as those of insectivorous species:

(i) At the top of large fruit trees (*Pteropus*);

(ii) Among the lower branches and bushes (*Rousettus* and *Cynopterus*).

(a) *Species hunting in the open air:* Such species are the majority. They explore large areas of air, searching for insects which fly out at sunset and at night. They are essentially the Vespertilionidae, Emballonuridae, and Molossidae. But the hunting territory is not exactly the same for the different groups.

The *Pipistrellus* and *Scotophilus* of the Vespertilionidae usually

hunt at middle heights, between trees and buildings. The territory is more or less the same as is worked during the day by flycatchers.

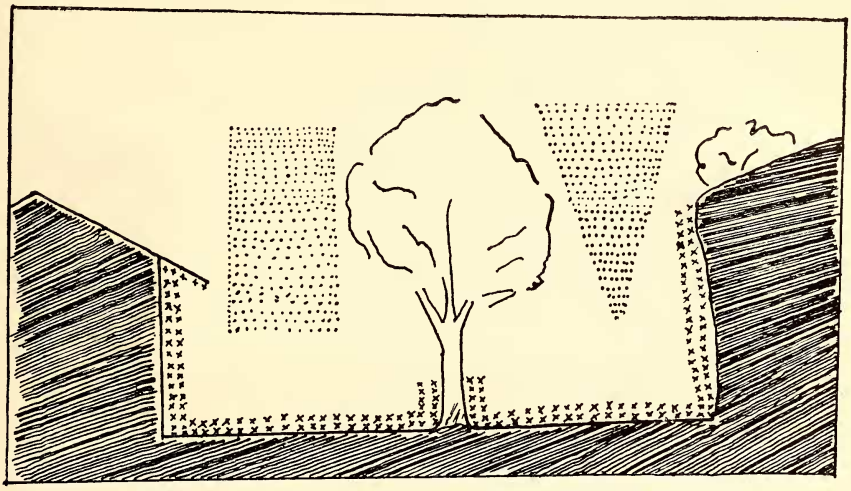

Fig. 1. ⁘ Hunting territory of *Pipistrellus*, *Scotophilus*, etc.; xxx Hunting territory of *Megaderma*

The *Taphozous* and Molossidae hunt higher above the ground, and explore the aerial open fields. They have during the night the territories of the swifts and the swallows.

(b) *Species hunting amid the foliage of trees:* The *Rhinolophus* belong to this group. They search for insects both flying and settled on the leaves and branches. They occupy during the night the territory of the warblers (Sylviinae) during the day.

(c) *Species exploring the ground, or the surface of rocks and barks of trees:* The *Megaderma* have this special hunting biotope where they search for terrestrial insects and small vertebrates. The feeding territory is similar to those of the shrikes, rollers, and the smaller birds of prey. The *Hipposideros* hunt over similar territory, not far from the ground and around the bushes.

Relations between the Morphology of the Species and the Nature of their Feeding Territory

The comparison with birds can be continued further. In the same way that the wings of warblers differ from those of the swifts, some bats have broad and short wings while others have them long and pointed. These differences, corresponding to the nature of their

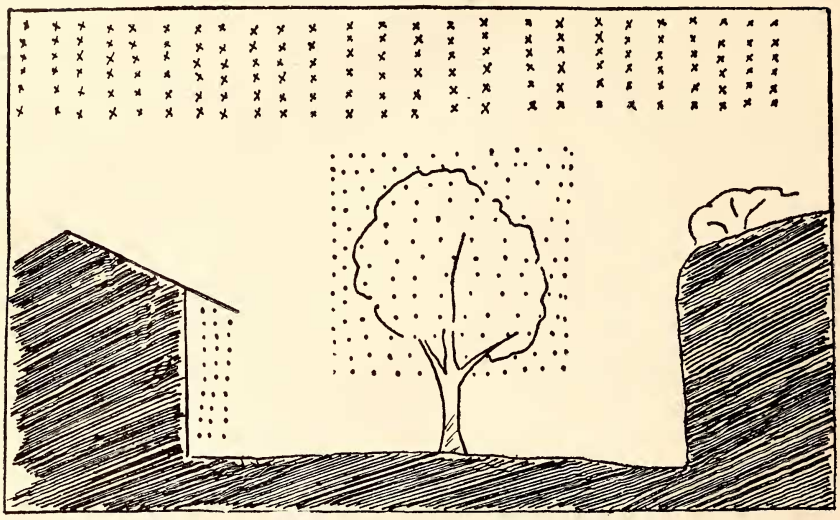

Fig. 2. ⋮ ⋮ Hunting territory of Rhinolophidae ; XXX / XXX Hunting territory of Molossidae and Emballonuridae

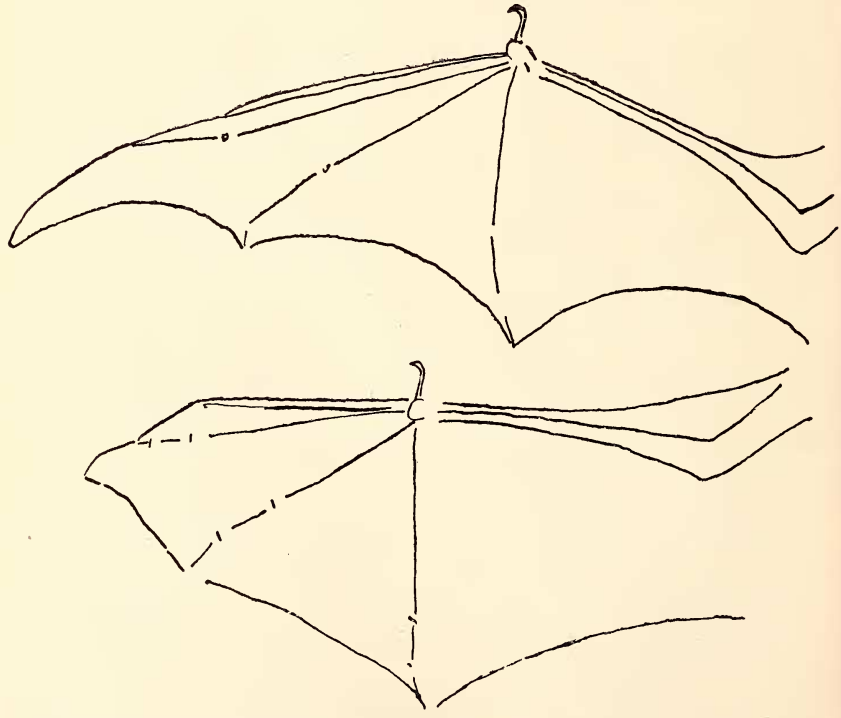

Fig. 3. *Above* : Wing of a strong flyer, *Taphozous saccolaimus* ; *Below* : Wing of a weak flyer, *Rhinopoma microphyllum*

respective feeding territories, are attained by changes in the length of the third finger, as illustrated in the accompanying sketches.

Reproduction

Study of the reproduction of bats is important to understand their general biology. Their sexual life can give an explanation of many aspects of behaviour, including cycles of displacement and their social life so peculiar in different species of Chiroptera. However, until recent years, methods and details of the reproduction of tropical bats remained unknown and mysterious. Several important studies have now shed light on the main aspects of the reproduction of Asian and African species. For Africa, Verschuren had given data of considerable value. For Asia, the placentation and sexual cycles of several Indian species are known by the important work of Moghe & Gopalakrishna, and their students. I have myself been able to obtain much information on the reproduction of Indian bats. My notes, in comparison with the researches of the Indian authors, may appear superficial, especially in relation to spermatogenesis and duration of pregnancy, because they lack the histological basis. On the other hand, I obtained in the natural environment data which would not be available in a laboratory. For this reason, I think these different studies will help to supplement and complete each other.

(*a*) Secondary sexual characters: Several Indian species have curious secondary sexual characters which are not easily visible in the skins preserved in museums. For this reason, the descriptions of the older authors are often incomplete, sometimes erroneous. The question needs to be re-examined with fresh specimens.

It may be noted that such characters sometimes occur in both sexes, sometimes in the males alone. In India they are not seasonal but permanent in all species, appearing after the juvenile stage, and sometimes well before sexual maturity is attained.

1. *Erectile beard:* The black beard appears in the young of *T. melanopogon* when about six months old (observations made in Kanheri). In the same time, the fur becomes lighter, of a sandy grey colour. This black beard is a good field character for the identification of the species in its diurnal biotope, and the more because the bat bristles up its beard when excited or frightened.

Six adult males of *Taphozous theobaldi* caught in North Kanara in May 1961 show a beard of the same type, but rufous and not black.

2. *Gular pouch:* Males of *T. longimanus* possess a very large inter-mandibular pouch (known as the inter-mandibular organ of Schaffer). The females also have the pouch, but less developed. A gland in front of the pouch produces a fatty and reddish secretion, with a strong and disagreeable smell; the same type of gland is present in *T. perforatus* and *T. kachhensis*. The gular sac appears early, being noticeable in the juvenile stage in *T. kachhensis*.

3. *Pectoral gland:* This gland is round and well developed in the male of *Taphozous kachhensis*, and absent in the females. Both sexes of *Otomops wroughtoni* have a deep and large gland at the base of the throat.

4. *Frontal sac:* Well developed in the males of *H. speoris* and *H. galeritus*.

5. *Variations in the colour of the fur:* Large variations have been noticed in the colour of the fur in several Indian species. In most cases, this polymorphism is unconnected with the distribution of the bats, and arises from purely individual variations of no taxonomic value. Several of the well-differentiated types of colour can be observed in individuals of the same colony, and we saw that Indian subspecies named on such differences cannot be sustained.

Colour variations may be due to age; except in *Pteropus* the young of all species, are grey. The true colour of the adults appears in the smaller species, after six months. Sexual dimorphism exists in three Indian species. The adult male of *C. sphinx* has bright rufous upper parts (sometimes the females also). The males of *R. leschenaulti* have the sides of the body washed with grey, the female being yellowish all over. The females of *T. melanopogon* are darker and browner than the males.

Finally, we do not know the reason for most of the variations of colours of bats. For instance, a red type is known in numerous species which are usually brown. *Tadarida aegyptiaca*, *Otomops wroughtoni*, *Rhinolophus rouxi*, *Hipposideros lankadiva*, and *H. fulvus*, *Pipistrellus ceylonicus*, and *Miniopterus schreibersi* have both types represented in the same colony. These phases of colour appear to have no connection with season or sex. Their biological significance remains to be elucidated.

(*b*) Periodicity of reproduction: Data have been collected on the reproduction of twenty-seven species. The greatest number have a well-marked periodicity. All the adult females of a

given species give birth to their young during one or two short periods regularly the same in the annual cycles. These dates vary from one species to another, but not for the individuals belonging to the same species.

In the state of our knowledge, unfortunately incomplete for several species, it seems that bats have three types of periodicity in India:

1. *One short and single cycle in the year—the young being born in a precise and restricted period:* This type of periodicity occurs in the great majority of Indian bats.

2. *One cycle in the year, but very long (March to September):* The greater number of females deliver in March, but others continue through the summer. This is the case with the small frugivorous bats and certain species of *Pipistrellus*.

3. *Cycles of reproduction free of the rhythm of the season, and following one another without stop:* One single species shows this type of cycle—*Taphozous longimanus*.

The analysis of the internal and external factors which determine the cycles of reproduction of the Indian bats show that the periodicity is firstly determined by the phylogenetic origin of the species; for instance, all the Indian Rhinolophidae (8 species) give birth to their young in spring, but the Molossidae do so in autumn. On the other hand, climatic factors particularly the rains in tropical countries may also be an important external factor in the determination of the time of their birth. In Africa and Asia, the majority of the species give birth to their young before the start of the rains, or just at the same time (cf. Verschuren for Africa, and Brosset for India).

(*c*) Sexual maturity, mating behaviour, pregnancy: I give here a summary of my notes published in another paper (cf. Brosset, La reproduction des chiroptères de l'Ouest de l'Inde. *Mammalia*, June 1962).

The small insectivorous bats, like *Hipposideros speoris* and *H. bicolor*, reach sexual maturity when 18-20 months old. Young individuals ringed in autumn in Elephanta were still immature the next spring. But one juvenile female ringed at Elephanta on 15 November 1959 (Bombay Nat. Hist. Soc., Ring No. 1357) gave birth to one young in May 1961. Owing to their slow development, the sexual maturity of the fruit bats probably takes longer.

Most activities of the bats are nocturnal and, owing to difficulty of observation, the sexual behaviour of this group of mammals is

practically unknown. The biological significance of pairs of bats resting or flying together is of little importance as very often the two individuals of the pair are found to be of the same sex. The copulation of *Megaderma spasma* was observed during the night in January 1961 at Kanheri. The male overlapped the female *modo ferrarum*. Each was hanging from the ceiling by a single foot only, and the hind part of their bodies was turned to the side, so that the two pubes were face to face. The free foot of each individual was used to hold the body of the other, probably in order to maintain the contact. It seems that the position of bats during copulation shows variations related to the systematic position of the species. Pairs of *Taphozous melanopogon* were seen in Kanheri in the position of copulation normal in most species of mammals.

The pregnancy of some Indian species has been studied carefully by Moghe & Gopalakrishna. These species belong to purely tropical groups of bats. Some new studies of bats belonging to the genera *Myotis* and *Rhinolophus* are needed in order to determine if they show in tropical countries such phenomena as delayed fecundation, or slackened pregnancy, as in the palaearctic regions.

In France, Courrier has proved that in *Miniopterus schreibersi* the foetus stops growing in winter and the pregnancy extends over about eight months. It seems the same occurs in India in this species. In the Robbers' Cave, I noticed that the pregnancy of this small insectivorous bat has a duration of at least five months.

(*d*) Number of young. How mothers carry young. Juvenile mortality: With a few exceptions, bats give birth to a single young. It is the rule for the whole order Chiroptera. In India, hundreds of *Taphozous*, *Rhinolophus*, and *Hipposideros* were seen carrying a single young, and no case of twins was noticed.

One case of twins has been recorded by Moghe in the fruit bats in *Cynopterus sphinx*. Twins seem rather frequent in *Megaderma spasma*, and are the rule for the Indian *Pipistrellus* and *Scotophilus*.

During growth, the position of the young varies according to the anatomy and ecology of the mother. In *Megaderma*, *Rhinolophus*, *Hipposideros*, and probably *Rhinopoma*, the young is carried by the mother in an inverted, ventral position. This position, which serves to give a good balance to both, is associated with the existence in the mother of the pubic false dugs to which the young affix themselves firmly by the mouth. The mother can fly with a young almost as big as herself. The other groups of bats have no false dug. In the fruit bats the position of the young is ventrally parallel. The young is

affixed to the natural dug with the body crossing the belly of the mother, so that she can carry a large young and fly with a good equilibrium. The species belonging to the genus *Taphozous*, and probably also the *Tadarida*, keep their belly in permanent contact with the stone surface of their diurnal roost, and the young cannot be accommodated under the belly; so the young are displaced to the side, under the wing. The mother cannot fly with a large young in such a position. Contrary to the previous species, the young of *Taphozous melanopogon* leave the mother early, being able to fly a long time before reaching adult size. In *Taphozous kachhensis* the young has found another position. It keeps itself on the back of the mother. Probably in the great majority of bats, the young is reared by its own mother. But in *Miniopterus schreibersi* the mother does not carry and suckle her own young. All the young are put together in a special cluster and reared by the community of the females. (For development and pictures of this behaviour, see Brosset, La reproduction des chiroptères Tropicaux. *Mammalia*, Tome **26**, No. 2, June 1962.)

Due to especially good conditions I was able to study the juvenile mortality in *Taphozous melanopogon* and *Rousettus leschenaulti* at Kanheri. In *Rousettus* about one-fourth of the young die in the early stages; in *Taphozous* one-fourth at the time of the separation from the mother (forearm 50-54 mm. in length for 34 dead young collected).

(*e*) Reproduction and social life: Recent researches have shown that the social life of the European species covers a short part of the sexual cycle. After fecundation the sexual segregation occurs and males and females live in separate roosts. Even the seasonal movements, which affect the two sexes differently, are under the influence of sexual rhythms. Unlike in the palaearctic area, in India such behaviour does not seem to be the rule. The segregation of the sexes is exceptional. In the great majority of species males and females live together the whole year. In addition to the colonies where both sexes are completely mixed, one can meet in India a second type of colony where males and females live in the same diurnal roost but in separate groups. This type of colony was observed in *P. ceylonicus*, *Rh. lepidus*, and *T. melanopogon*. In these species, the males are frequently scattered around a nucleus of females, sometimes several colonies of males occupying secondary diurnal roosts in the vicinity of the main roost, where only females may be found. These observations show that among bats, the

females are dominant, and occupy regularly the better and safer portions of the biotope.

The only species in which a rigorous segregation of the sexes in India is proved is *Rhinolophus rouxi*, though two cases of segregated colonies were observed in *Rhinopoma hardwickei*.

In colonies where males and females live together, the sex ratio is far from balanced. In fact, with a few exceptions, the females are more numerous than the males. In India, the fact was brought to light for the first time by Humayun Abdulali (cf. *J. Bombay nat. Hist. Soc.* **48** : 423-427; 1949). For various countries, the same observation has been made by numerous authors. Baker & Bird 1936, Blanford 1888, Brosset & Caubère 1950, Casteret 1938, Gopalakrishna 1947, 1950, Ramakrishna 1951, Nimsatt 1945, etc.

What is the reason for this unbalanced sex ratio in bats? The only species for which sufficient statistical data are available is *Miniopterus schreibersi* in France. In the colony of Rancogne 1747 newly born were examined, of which 877 were males and 870 females. The sex ratio is equal at the time of the birth of the young. Nevertheless, adults caught at the same place showed 897 females against only 700 males. We saw that, for this species, both sexes live together indiscriminately mixed, and the higher mortality of the males does not appear to be connected with any ecological factors. The explanation for this unbalanced sex ratio in bats may lie in physiological factors, connected with sexual endocrinology.

Hibernation

In temperate and cold countries, bats hibernate. This hibernation often broken by short periods of activity is practically continuous from October to April in middle Europe, where bats are known to hibernate even in summer. Practically nothing was known about the hibernation of bats in tropical countries, and I made special efforts to ascertain if such behaviour could be observed in Indian species. For this reason the degree of activity of all individuals observed was noted. Bats found in a state of torpidity were caught, and their reactions carefully observed. Experiments were made to ascertain whether hibernatorial faculties existed in species which did not hibernate under natural conditions. Twelve species were experimentally tested by repeated cooling.

Observations in the field throughout the year prove that the species belonging to the group of the fruit bats and also of the genera *Taphozous*, *Rhinopoma*, *Megaderma*, and *Hipposideros* never hiber-

nate in natural conditions. Probably, it is the same for the Molossidae, *Tadarida,* and *Otomops.* On the other hand, the various species of Indian Rhinolophids and Vespertilionidae were frequently found all over western India in a state of complete hibernation.

The cooling experiments were made with a refrigerator, where bats were placed, each in a bag, a short time after their capture (internal temperature 8° C.; duration of the experiment: from 6 to 36 hours; control of tested individuals: they were examined on an average once every five or six hours—for a detailed account of these experiments, see Brosset: L'hibernation chez les chiroptères Tropicaux. *Mammalia,* Tome **25**, No. 4, December 1961).

During these experiments, four types of reactions were noticed:

(i) The bats tolerate the cooling experiment, do not enter into any hibernatory stage, and fly away easily immediately after 24 hours of experiment. Various *Taphozous, Megaderma,* and the larger *Hipposideros* showed this type of reaction.

(ii) After a period of restlessness, the bats enter into complete hibernation; at the end of the experiment (24-36 hours) the bats recovered progressively (in periods varying from 15 to 30 minutes) the normal state of activity, and did not seem to suffer from the experiment. *Rhinolophus* and Vespertilionidae showed this type of reaction.

(iii) After a few hours, the tested individuals entered a state of torpidity which looked like hibernation, but from which they did not recover and died. *Rousettus leschenaulti* reacted in this manner to the cooling experiment.

(iv) The tested bats did not endure the cooling experiment and died after a few hours. The small species of *Hipposideros* showed this reaction.

Two important facts are established by these observations and experiments:

(*a*) The hibernation of the Chiroptera is not entirely connected with the thermic regulation of the body; it may be due to causes other than climatic conditions. Tropical species pass through periods of complete hibernation, Palaearctic species are frequently found hibernating in summer, and the same type of hibernation has been observed in rodents, and even in birds. The Hummingbirds of the Andes, which sleep in caves during the night, have a rhythm of torpidity independent of the external variations of temperature. Further, the hibernatorial rhythms are individual; bats in a state of

complete hibernation may be found resting beside others of the same species in a state of absolute activity.

(*b*) The field observations strengthened by experimental research and by data recorded in Africa show that bats like *Taphozous*, *Megaderma*, *Rhinopoma*, and *Hipposideros*, which do not possess hibernatorial faculties, are restricted to countries with warm winters, i.e. the tropical and equatorial areas. The Rhinolophids and Vespertilionids, which all hibernate, have been able to settle in temperate and cool countries. It seems that the presence and/or absence of hibernatorial faculties in the different groups of bats has determined their distribution over the world.

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